Rolf Hagedorn July 20, 1919 – March 9, 2003

Personal Remarks

I first met 'Herr Hagedorn' in Winter 1975/76, at his Colloquium on the Statistical Bootstrap Model (SBM). After the lecture and some discussion that followed I asked if I could visit him at CERN and he suggested I consider a short term position application. I arrived as CERN-fellow September 1977.

- Herr Hagedorn was an extraordinary teacher;
- Herr Hagedorn was available to help those who were in need.

A few pages on Hagedorn's path in life and science follow. More reminiscences in: **"Melting Hadrons, Boiling Quarks..."** book: `http://www.springer.com/de/book/9783319175447`, prelim version (21.5mB)

`http://www.physics.arizona.edu/~rafelski/PS/hagedornJR_proof.pdf`

Johann Rafelski *Editor*

Melting Hadrons, Boiling Quarks

From Hagedorn Temperature to Ultra-Relativistic Heavy-Ion Collisions at CERN

With a Tribute to Rolf Hagedorn

This book shows how the study of multi-hadron production phenomena in the years after the founding of CERN culminated in Hagedorn's pioneering idea of limiting temperature, leading on to the discovery of the quark-gluon plasma – announced, in February 2000 at CERN.

Following the foreword by Herwig Schopper – the Director General (1981-1988) of CERN at the key historical juncture – the first part is a tribute to Rolf Hagedorn (1919-2003) and includes contributions by contemporary friends and colleagues, and those who were most touched by Hagedorn: Tamás Biró, Igor Dremin, Torleif Ericson, Marek Gázdzicki, Mark Gorenstein, Hans Gutbrod, Maurice Jacob, István Montvay, Berndt Müller, Grazyna Odyniec, Emanuele Quercigh, Krzysztof Redlich, Helmut Satz, Luigi Sertorio, Ludwik Turko, and Gabriele Veneziano.

The second and third parts retrace 20 years of developments that after discovery of the Hagedorn temperature in 1964 led to its recognition as the melting point of hadrons into boiling quarks, and to the rise of the experimental relativistic heavy ion collision program. These parts contain previously unpublished material authored by Hagedorn and Rafelski: conference retrospectives, research notes, workshop reports, in some instances abbreviated to avoid duplication of material, and rounded off with the editor's explanatory notes.

In celebration of 50 Years of Hagedorn Temperature

Physics

ISBN 978-3-319-17544-7

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Rafelski *Ed.*

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With a Tribute to Rolf Hagedorn

Springer Open

Johann Rafelski, 'Hagedorn' Session opening, ICNFP2015, August 26, 2015

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Curriculum vitae - Curriculum vitae:

I was born in 1919 at Wuppertal-Barmen. My parents, Max and Linda Hagedorn (born Reinecke), are both alive today. At the age of six I entered the elementary school and four years later the "Städtisches Realgymnasium Wuppertal-Barmen" where I passed the final examination (Abiturium) Easter 1937. Thereafter I joined the Reichsarbeitsdienst and in November 1937 the Armed Forces since I intended to complete my military service before beginning the university course in order not to interrupt it. But at the end of 1939, when I was to be released the war began and I had to stay with the Luftwaffe. During the war, I spent a long time in North Africa where I was captured May 1943 and was brought to the USA. There, in the prisoner-of-war Camp Crossville (Tennessee) I began studying Mathematics, Physics and also a little History of Arts and related topics. Further, I had to teach a high school class in Physics on a basic level. After having returned in January 1946, I continued my studies in Göttingen, where I decided to become a theoretician. Consequently I was a pupil of Prof. R. Becker. In 1950 I passed the diplom-examination with a work on the theory of the Lamb-shift in nonrelativistic Quantumelectrodynamics (not published). This was followed by a paper on the theory of Barium-titanate as a thesis in spring 1952. Since June 1952 I am working at the Max-Planck-Institut für Physik, Göttingen, on nuclear physics, especially on the evaporation stars in nuclear emulsions. (See list of publications)

2

Continuez sur une nouvelle feuille si necessaire.
(Continue on a separate sheet if necessary)

Références - References

Prof. W. Heisenberg, Max-Planck-Institut für Physik, Göttingen

Prof. R. Becker, Institut f. theoret. Physik der Universität Göttingen

IX. *Publications* - Publications:

1) Sichtbarmachung der Drehimpulsachse des kräftefreien Kreisels, Zs. f. Physik 125 (1948) 542
2) Statisches Modell von Bariumtitanat bei Zimmertemperatur, Zs. f. Physik 133 (1952) 394
3) (zus. mit W. Macke): Theorie der Verdampfungsprozesse bei Kernexplosionen, in: Kosmische Strahlung, 2. Aufl., Berlin 1953, S. 201
4) Die Gross-Transformation in: Kosmische Strahlung, 2. Aufl., Berlin 1953, S. 564
5) Kernverdampfung und Auswahlregeln, Zs. f. Naturforschung, im Erscheinen

22.5.52
At this occasion the following CERN point ...

Date: 27. Jan. 1954

SIGNATURE:
Rolf Hagedorn

Hagedorn applies at age 34.5 to join the future CERN, with references from Werner Heisenberg and Richard Becker, and thermal physics, cosmic event stars under his belt. He is hired by J.B. Adams, first to help build the PS; now D.G., J.B. Adams assigns him effective January 1, 1961 to a permanent position in the CERN Theory Division charging him with:

Dr. Rolf Hagedorn
Scientific and Technical
Services

CERN/6824

Personal and Confidential

28 September, 1960

Dear Dr. Hagedorn,

It gives me great pleasure to inform you that it is my intention to offer you an indefinite appointment with this Organization to take effect from 1 January, 1961. This date has been decided in accordance with the present policy of CERN not to offer such appointments to selected staff members normally before their completion of at least six years' service in the Organization.

This indefinite appointment is for a post in the Theory Division of CERN.

It is intended that you devote your time partly to investigations and computing problems associated with the experimental programmes of CERN, such as the use of statistical models for predicting particle production, and partly to those aspects of theoretical physics that will enable you to keep abreast of modern developments in

1964/65 Revolution: Three new ideas merging today

- $T_{\rm H}$ & SBM hadronic matter
- made of Quarks
- Higgs & Standard Model of Particle Physics

Our timeline:

1. 50 years ago – Melting hadrons: birth of hadronic matter
2. 35 years ago – Boiling quarks: at $T_{\rm H}$ hadrons $\Leftrightarrow$ quarks
3. 15 years ago – Quark-gluon plasma discovery
4. Today – Searching with QGP for new physics

Particle production

WITHDRAWN

Hagedorn 1960-1964: Fermi model produces too few pions - could this mean particles are distinguishable ?

9716/TH.483
12 October 1964 PRELIMINARY VERSION

THERMODYNAMICS OF D I S T I N G U I S H A B L E PARTICLES -
A KEY TO HIGH ENERGY STRONG INTERACTIONS ?

R. Hagedorn
CERN - Geneva

A B S T R A C T

A new kind of thermodynamical model for strong interactions at high energies is proposed. We start from the fact that strong interactions produce so many possible particle states (from π over its resonances to nucleons, strange particles and their resonances, up to highly excited "fireballs") that in an actual process each of these states practically never occurs more than once. We use this in order to treat the very first instant of a high-energy collision by statistical thermodynamics of a system of an illimited number of d i s t i n g u i s h - a b l e particles. The model shows surprising properties : there exists a universal highest possible temperature T_o of the order of 150-200 MeV (corresponding to $\approx 10^{12}$ °K) which governs all high-energy processes of strongly interacting particles, independently of the actual energy and independently of the particle number, from cosmic ray jets down to elastic scattering.

ARCHIVES

Remarks to the "PRELIMINARY VERSION" of

THERMODYNAMICS OF D I S T I N G U I S H A B L E PARTICLES -
A KEY TO HIGH ENERGY STRONG INTERACTIONS ?

R. Hagedorn

I have written and distributed this paper too early. The logical difficulty mentioned on p. 41 has been removed as follows and the result is disappointing :

Now everything depends on the asymptotic behaviour of the mass spectrum $\rho(m)$

1) if $\rho(m)$ grows faster than exponentially, log Z diverges for all $T > 0$. No thermodynamics is possible.

Jan. 1965: Nuovo Cim. Supp. **3** 147 (1965): SBM, T_{H}

65/166/5 - TH. 520
25 January 1965

STATISTICAL THERMODYNAMICS OF STRONG INTERACTIONS AT HIGH ENERGIES

R. Hagedorn

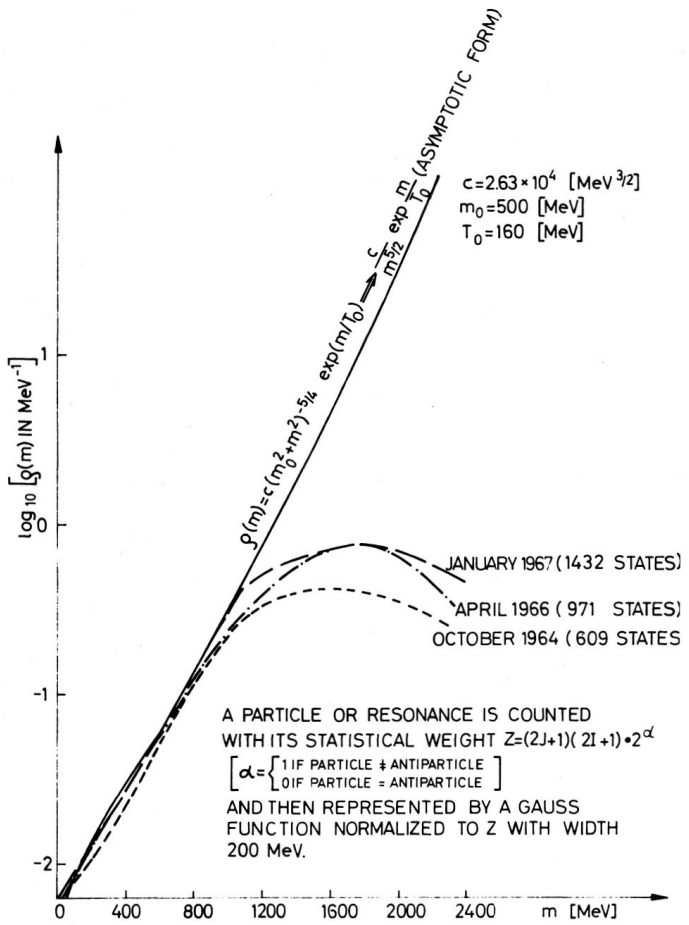
CERN - Geneva

ABSTRACT

In this statistical-thermodynamical approach to strong interactions at high energies it is assumed that higher and higher resonances of strongly interacting particles occur and take part in the thermodynamics as if they were particles. For $m \to \infty$ these objects are themselves very similar to those which shall be described by this thermodynamics. Expressed in a slogan: "We describe by thermodynamics fire-balls which consist of fire-balls, which consist of fire-balls, which ...". This principle, which could be called "asymptotic bootstrap", leads to a self-consistency requirement for the asymptotic form of the mass spectrum. The equation following from this requirement has only a solution if the mass spectrum grows exponentially:

$$\rho(m) \xrightarrow[m \to \infty]{} \text{const.} m^{-5/2} \exp\left(\frac{m}{T_o}\right).$$

T_o is a remarkable quantity: the partition function corresponding to the above $\rho(m)$ diverges for $T \to T_o$. T_o is therefore the highest possible temperature for strong interactions. It should - via a Maxwell-Boltzmann law - govern the transversal momentum distribution in all high energy collisions of hadrons (including e.m. form factors, etc.). There is experimental evidence for that, and then T_o is about 158 MeV ($\approx 10^{12}$ °K). With this value of T_o the asymptotic mass spectrum of our theory has a good chance to be the correct extrapolation of the experimentally known spectrum.



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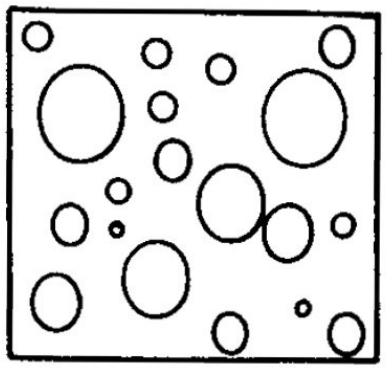
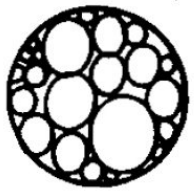
SBM=Statistical Bootstrap Model

A macroscopic system



compress

a "particle"



with total energy E
given volume V
density of states $\sigma(E,V)$

with total energy m
self-confined to its
natural volume V(m)
density of states $\rho(m)$

T_H : limiting temperature

Idea yields exponential mass spectrum: $\rho \propto \frac{e^{m/T_H}}{(m_0^2 + m^2)^{a/2}}$

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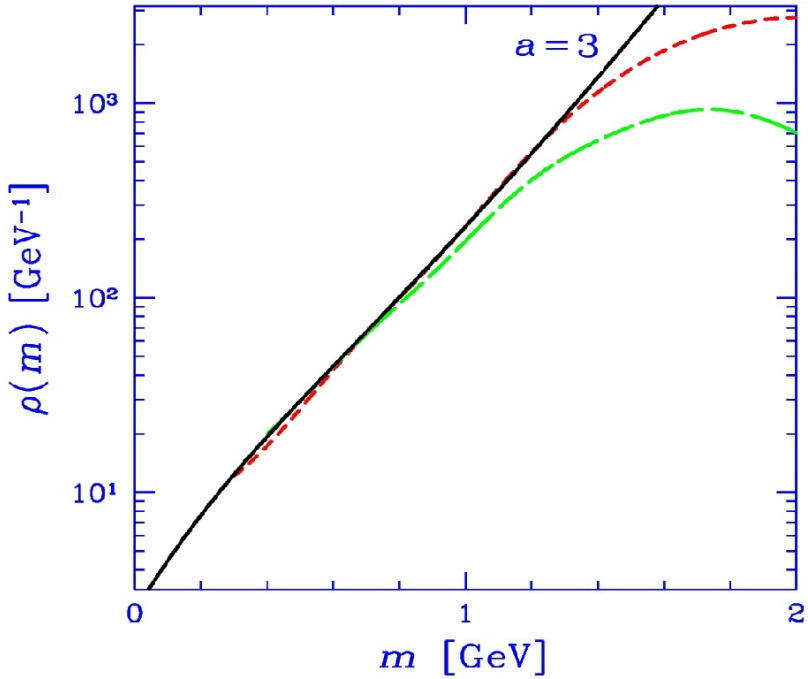
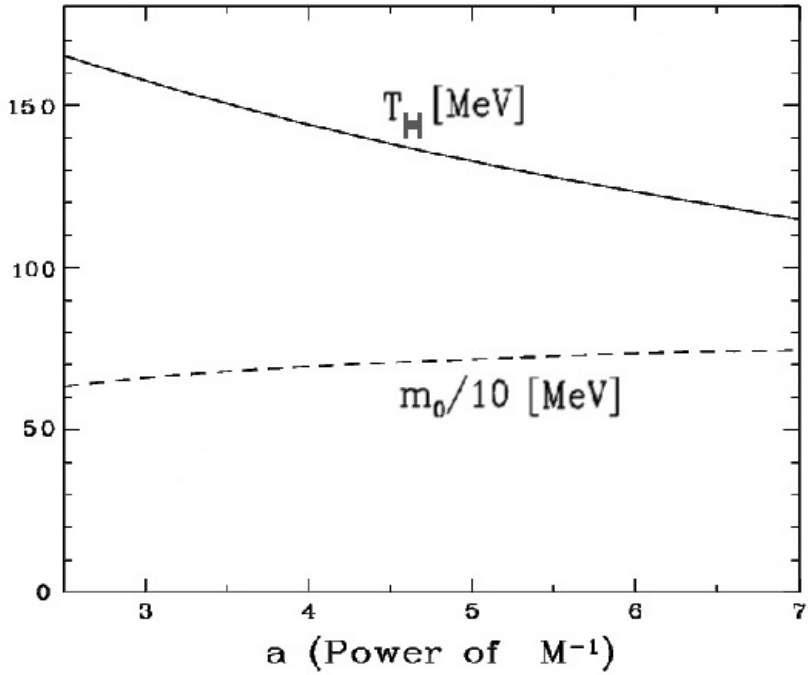
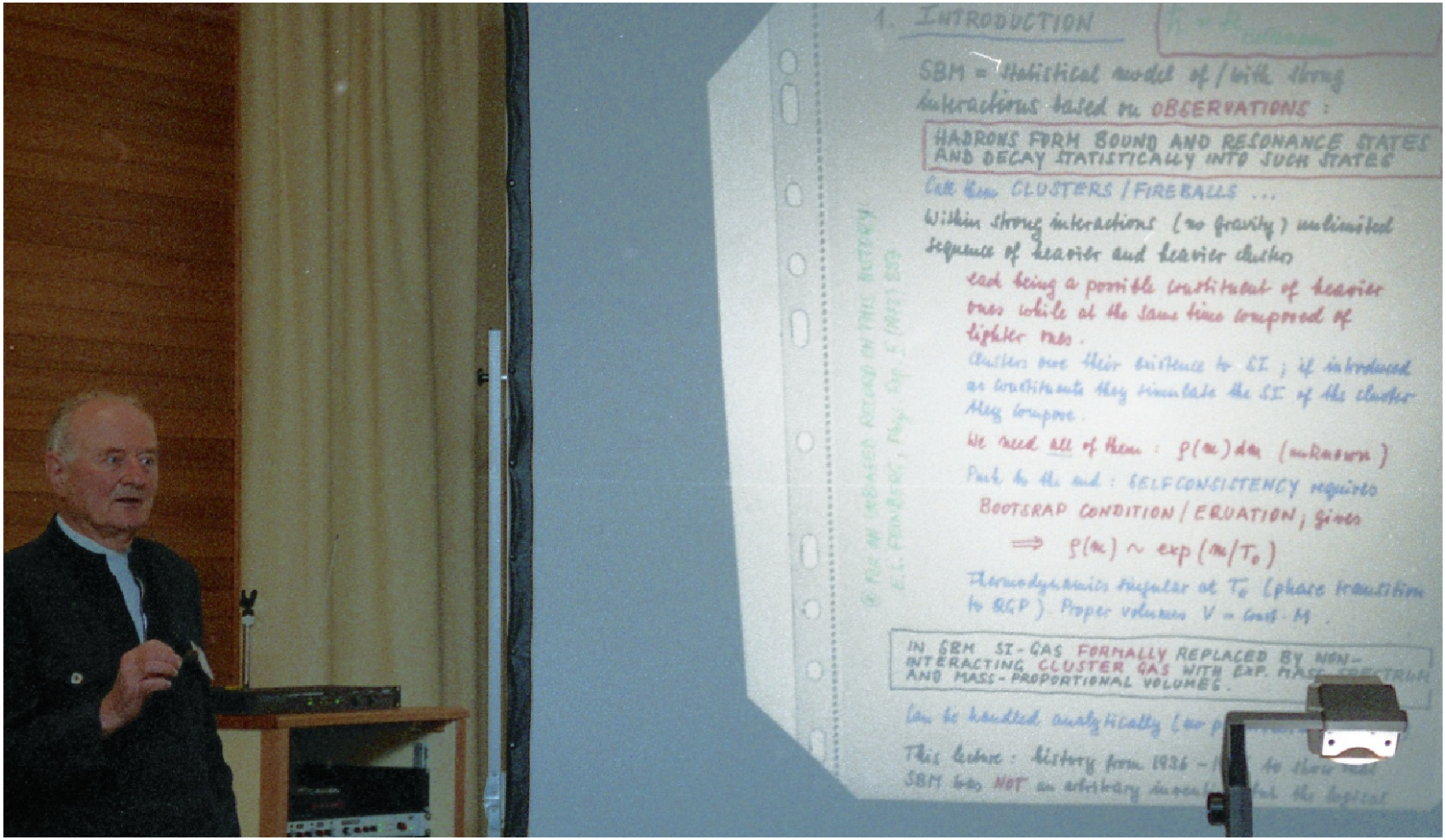
Experimental mass spectrum defines T_{H}





To fix T_{H} in a limited range of mass need prescribe value of a obtained from SBM. In 1978 we noted that at T_{H} sound velocity vanishes. This creates another way of fixing T_{H} both in experiment and in lattice QCD. For detail see `http://arxiv.org/abs/1508.03260`.

Valedictorian Lecture 1994



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